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Progress Report

for

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Studies of Excited Species in Planetary Upper Atmospheres

for the period 1 January, 1995 to 31 December, 1995

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Progress Report

During the course of the last year, we have been studying various aspects of the chemistry of excited states in the atmospheres of Venus, Mars, and Titan.

We have investigated the solar activity variation of the dayside ionosphere and thermosphere of Venus by constructing models and comparing them to measured electron density profiles from PV ORO data. Our neutral models were the VTS3 models of Hedin et al (1983), and we included 14 ions and 5 neutral species. The solar fluxes adopted were the f79050n and sc21refw spectra from Hinteregger (private communication). We found that the variability in the ion production rates and density profiles at the peak is much smaller than that at higher altitudes. The relative lack of variability in the peak density is partly due to the destruction of the ion by dissociative recombination, which produces a square root dependence of the density on the production rates. The production rate of O^+ at 200 km increases by a factor of 9 from low to high solar activity, and the density varies by a slightly smaller factor, since the loss is by reaction with CO_2, which only increases slightly with solar activity. Thus the large inferred change in the day-to-night transport of ions is easily explained as being due to a combination of changes in the dayside O^+ densities and the changing height of the ionopause.

We have also found that the NO^+ density profile in the ionosphere of Venus is sensitive to the assumed rate coefficient for the reaction:

$$N + CO_2 \rightarrow NO + CO. \tag{1}$$

This rate coefficient has not been measured and only an upper limit of $1.6 \times 10^{-16}\,cm^3\,s^{-1}$ (Brown and Winkler, *Angew. Chem.* *9*, 181, 1970) is available. We have found that an NO^+ peak appears at low altitudes on the dayside when the rate coefficient is near the upper limit. Without the reaction, no peak appears. (Research carried out with grad student Penny Zhou.) A manuscript on this subject is in preparation, and some of the results are briefly discussed in a chapter entitled "The ionosphere of Venus: Solar activity variations" written for the University of Arizona Press book *Venus II.* The manuscript is currently being reviewed, and a preprint in enclosed. A similar study of the dayside ionosphere of Mars was published this year, and a reprint is attached.

Work with Roger Yelle (Boston University) on the ionosphere of Titan has revealed that the major ion is not $HCNH^+$, as other models have predicted, but a combination of various large hydrocarbon ions. The results are bfiefly discussed in a manuscript entitled "Hydrocarbon ions in the ionospheres of Titan and Jupiter", which is being published as a chapter of a book entitled "Dissociative recombination: Theory, experiment and applications", edited by Mitchell, Zajfman, and Rowe. A preprint is attached, and a letter for GRL is in preparation.

We have carried out Monte Carlo calculations in order to infer the isotope differentiation in N_2^+ dissociative recombination as a function of electron temperature and ion temperature. This process is important as an escape mechanism from Mars and source of the enhanced ratio of ^{15}N to ^{14}N found on Mars from the Viking mass spectrometer measurements. The dissociative recombination process is particularly important because it produces a large fraction of the escaping N atoms, and because there is an isotope effect inherent in the mechanism. Our results are somewhat different from those of Max Wallis, who carried out an analytical calculation for much smaller electron temperatures than those reported by Mantas and Hanson (1988) from Viking RPA measurements. We have found that the escape probability for both ^{15}N and ^{14}N is a slightly increasing function of electron temperature, but (surprisingly) the escape probability of ^{14}N is a slightly decreasing function of ion temperature. Since the escape probability of ^{15}N is an increasing function of ion temperature, the ratio of escape probabilities increases fairly strongly with ion temperature. A talk based on this work was presented at the Fall 1995 AGU Meeting. We would like to incorporate the effects of the decrease in the dissociative recombination cross section with increasing velocity and the difference in the vibrational energy levels of $^{15}N^{14}N^+$ compared the $^{28}N_2^+$ before the results are published. (Work carried out with A. Hać).

I also completed and submitted an invited chapter entitled "Aeronomy", which is to be published in the *Atomic, Molecular and Optical Physics Reference Book*, edited by Gordon Drake, and is *in press* at the American Institute of Physics Press. A preprint is enclosed.

Work Statement for the Next Year

During the year January 1–December 31, 1996, we would like to refine and publish our Venus solar activity variation and Titan ionosphere results from this year. As mentioned previously, there are a couple of potentially important effects that we have not yet included in the Mars study of $^{15}N/^{14}N$ isotope differentiation of N_2^+ dissociative recombination: the effect of the decrease in cross section as velocity increases, and the change in the vibrational energy levels of $^{15}N^{14}N^+$ as compared to $^{14}N^{14}N^+$. We will do this over the next two months.

We are also committed to modeling the ancient Mars ionosphere as part of a study of the evolution of volatiles on Mars. Steve Bougher is modeling the ancient Mars thermosphere, and our model will be carried out with his neutral model as the background atmosphere. Since we are going to present a talk on this subject on February 12, 1996, we will do the bulk of this work during the next 30 days. Then we will prepare it for publication.

We would like to begin work on the metal ion chemistry on Venus and Mars, a collaboration with J. Grebowsky at GSFC. This project was proposed last year, but reorganization at Goddard, and my move to Dayton intervened.

A natural extension of our work on the hydrocarbon ion chemistry of Jupiter would be a model of hydrocarbon ion in the auroral ionosphere, which we hope to begin within the next three months. A Physics masters student at Wright State University (John Perry) will be doing his thesis on heating efficiencies in the Jovian auroral zone. This is particularly relevant because the Jovian aurora is the most powerful in the solar system, and is predicted to affect the thermosphere at mid-latitudes as well. Now that Galileo is at Jupiter, the topic has become particularly relevant.

The budget for 1996 follows.

Second Year Budget for NAGW-2958 (SUNY 2382B)

	Jan. 1, 1996– Dec. 31, 1996
I. Salaries	
A1. Professor Jane Fox	
1/9 Academic Year	$ 7316
2.27 Summer Months	16,608
B. Graduate Student Assistant (30% effort)	16,995
C. Undergraduate Assistant (140 hours per academic yr; 125 hours summer)	1855
II. Benefits (32.5% (1996), of I.A1.)	7775
(11% of I.B.)	1869
(4% of I.C.)	74
III. Travel	
A. One person to AGU or DPS meeting Assume west coast (Airfare $ 750, 5 days per diem @$137/day=$685, Conference Fee $160, Miscellaneous $50 Total = $1625)	1625
IV. Supplies (Magnetic tapes and computer paper, office supplies, books and journals)	470
V. Publications (e.g., 6 pages JGR @$150/page)	900
VI. Miscellaneous (xeroxing, photo, phone, postage, fax, workstation maintenance etc.)	515
Total Direct Costs	56,002
VIII. Overhead (48.1% of I-VI)	26,937
TOTAL	$82,939